SMART MEASUREMENT FOR LONG RANGE COMMUNICATION with ANTENNA TRACKER

Submitted as a requirement of completing the Bachelor Study Program in the Department Electrical Engineering

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ELECTRICAL ENGINEERING STUDY PROGRAM

FACULTY of ENGINEERING

UNIVERSITAS MUHAMMADIYAH SURAKARTA

2017

APPROVAL

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SCIENTIFIC PUBLICATION

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Thursday, August 3rd 2017
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Abstract

Sekarang, komunikasi adahal hal yang sangat penting bagi sebaian orang untuk medaptkan informasi atau suatu data. Teknologi komunikasi pada pesawattanpa awak atau yang biasa dipanggil dengan sebutan drone sangat berkembang cepat. Dengan perkembangan yang cepat dapat menemukan hal baru dan menutupi kekurangan-kekurangan dalam teknologi pesawat tanpa awak seperti sistem komunikasinya. Hal yang menarik dari teknologi tanpa awak adalah suatu sistem yang bisa melacak keberadaan pesawat itu. Biasa perangkat ini disebut dengan Antenna Tracker. Kegunaan dari antenna tracker adalah melacak posisi bedasarkan sudut. Supaya antenna selalu Line of Sight terhadap pesawat, ketika antenna yang digunakan adalah jenis directional antenna. Ketika antenna untuk sustu sistem trasnmisi atau pengiriman data menggunakan antenna directional sudut pancarnya lebih kecil dari yang jenis omni, namun jarak jangkauannya lebih jauh. Demikian usaha untuk membuat radiasi dari antenna untuk menerima data dari pesawat selalu Line of Sight dilakukan dengan menggunakan beberapa rumus dari data yang diolah bedasarkan koordinat pesawat dan koordinat dari antenna itu sendiri. Lalu dari kedua data itu akan nemeukan nilai bearing yang akan menentukan arah hadap dari antenna. Lalu untuk menghadap ke arah ketinggian digunakan data ketinggian dari pesawat lalu akan dikalkulasikan ketinggian menjadi sudut yang akan menggerakan antenna kearah tinggi pesawat dengan rumus trigonometri. Alat untuk penggerak ini menggunakan motor servo yang mana langsung dalam pemmrosesan nilai digunakan adalah sudut sebagai inputannya.

Kata Kunci : *GPS, Compass, Tracking, Antenna Tracker, Azimuth, UAV.*

Abstract

Now days the commnunication to be important thing, for some people to get some informations or datas. The technology communication in Unmanned Aerial Vehicle (UAV) or called drone runs very fast. With the fast development encourages new things to cover the shortfall from the main purpose of communicating. One thing that impressed is some tracking system to make the antenna always line of sight to the drone or UAV to transmited and recieved datas. The developed with a device that can track the position of a sender of data using wireless communication with a frequency that is used. With other terms that antenna tracker, a device that could track the state of a sending device in the form of direction and distance in general. This device utilizes the work of a GPS sensor and then use a combination of several mathematical formulas to determine the data that we need to keep track of a sender device. The formula like haversine, bearing, azimuth and trigonometry. This systems any payload or called by sensder device that transmit data of latititude, longitude from GPS sensor. For the altitude used the barometer preasure sensor. In the ground side any tracking system that recieved the data from the payload. The tracking system has GPS sensor, compass sensor for define the value of bearing. This systems using wireless telemetry that operate at 915 Mhz for transmitting and recieving datas. In the other side any *some graphical user interface for displaying the datas all the payload, tracking system, the azimuth, distance between payload to antenna and etc. This antenna tracker system has two servo drive form with two degrees of freedom in the form of X and Y axes.*

Keyword : *GPS, Compass, Tracking, Antenna Tracker, Azimuth, UAV.*

1. INTRODUCTION

Technology is moving fast. Many sides that moving fast, from communications, programming, interfacing, and signaling. Now the scientists developing the vehicles that can measuring the conditions in space area. Not only for measuring the vehicles usually for to doing some tasks that the data's that gets must sent to the ground station in the earth by the antenna. Antenna is the device that can transform the electromagnetic wave for communicating in free space. Any two kinds off the antenna that is omnidirectional and directional. The Omnidirectional usually for short range and but the radioation to all direction almost 360 degree. And directional have a long range but the degree is small.

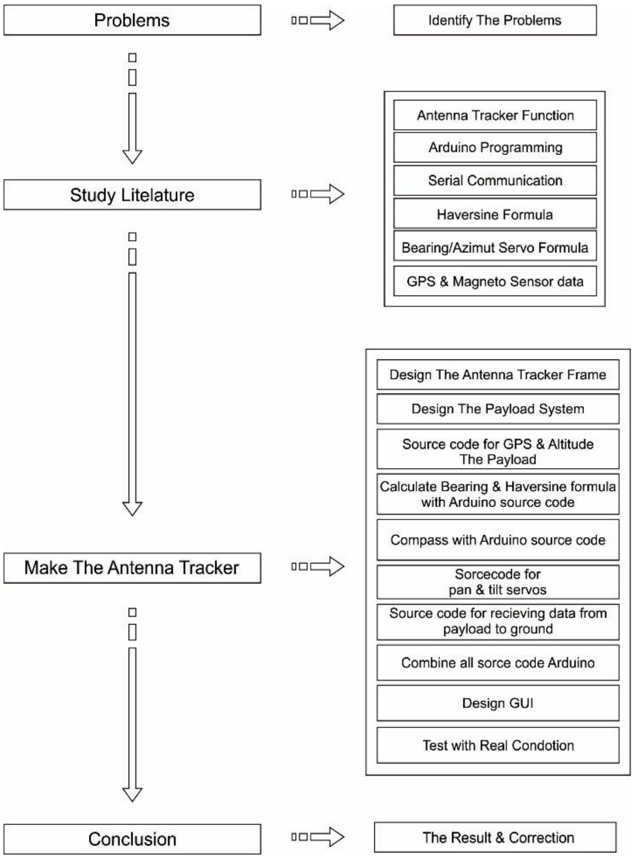
So many people need for long range communication should be choose the direction antenna type. But how to make the antenna type directional always line of sight, need some systems to controll it by automatically for covered all radiation from signal. Its call by tracking system, the controlling is recieving data from the aircraft that flying and recieving in the ground for calculate the distance, the bearing and the altitude. Any two GPS sensors for this systems,for position of the aircraft or payload and the antenna in the ground. The telemetry for trasnmitting system using 915 MHz with biquad antenna.

The data that transmitted to the groung is latitude, longitude and altitude by telemetry system. After recieving data it will process by arduino as controller unit, comparin and calculate the data in the ground for controlling the servos motor. Servos motor control by PWM value that processed the microcontroller from the sensors and data that recieved by some formula. The Servo motor that used is 180 degree for pan direction and 90 degree for tilt direction.

A graphical user interface showing the data's like latitude payload, longitude payload, altitude payload, latitude antenna, longitude antenna, azimuth, distance between antenna and aircfrat, the heading of compass. The antenna controlling unit directly connected by USB to laptop unit. And will show by some gauges, map and simple numbers by realtime. The other side the graphical user interface also has a logging system to saving the data after the to do some missions.

2. METHOD

This activity had been start from early semester, and start to arrange and design of the tracking system. And start for design the antenna tracker system from the payload and the antenna tracking system.

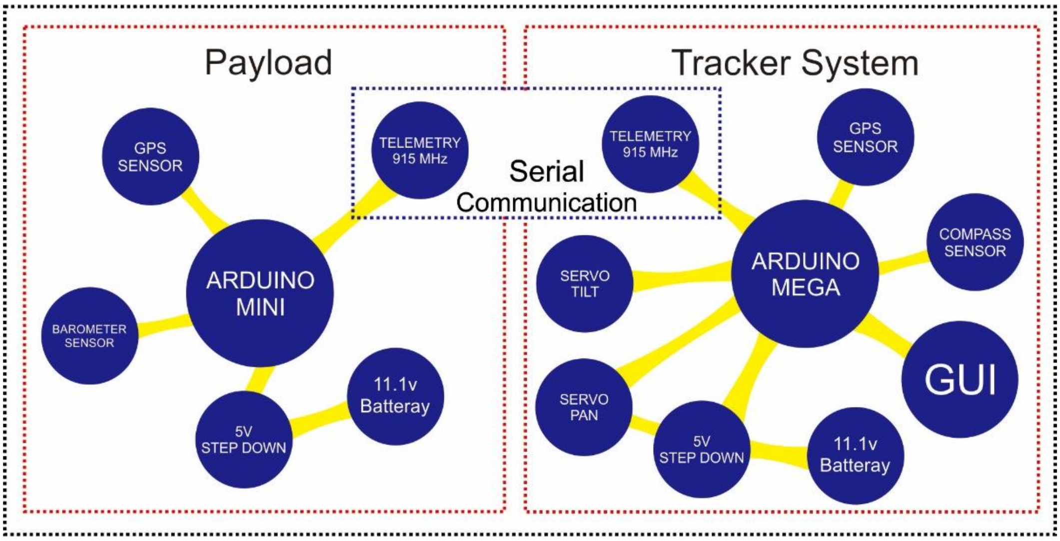


Picture 1. Scheme Activity

The fisrtly in the diagram block, is identifying the what the problem. Clearly the problem is how to make the groung station can communicate with the payload or aircraft inthe air with long range, or always line of sight. After this, the study literature like understanding about the way, how to build the antenna tracker with some refferences. How to using compass sensor, the function. How to using the serial communication between two devices. And some formula refferences mathematical methode for antenna tracker system.

The design of the antenna tracker control system is divided into two parts, namely the design of hardware (electronic system) and software design (source code and graphical user interface). The design of hardware includes all the hardware used on the antenna tracker as the reciever and the payload as the transmitter of the data’s. The design of the software contains the CMPS11 sensor reader algorithm, GPS, data transmission via telemetry radio 915Mhz, controlling antenna motion against the azimuth angle through servo, and sending data from payload to antenna.

2.1. Design The Hardware System



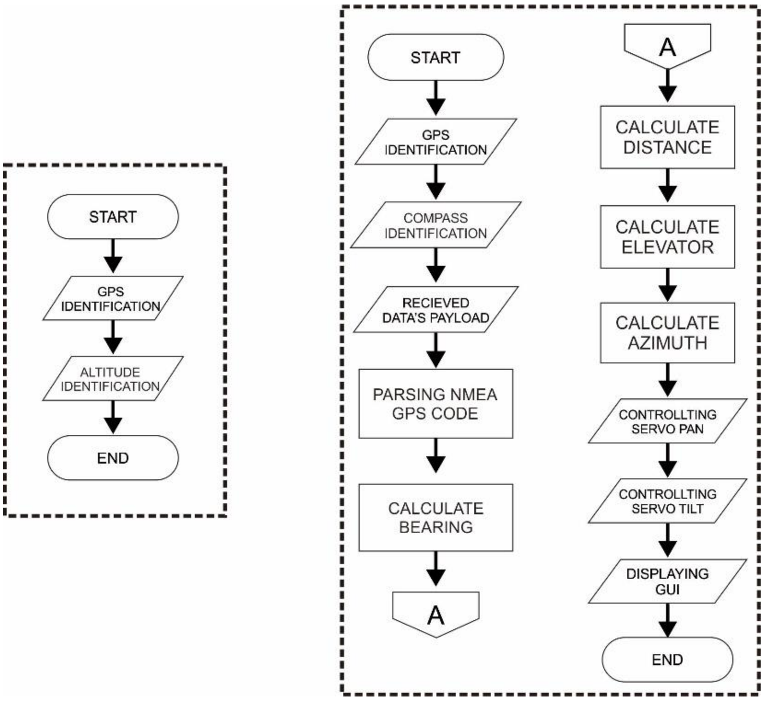
Picture 2. Map of Antenna Tracker Components

Like the map bellow, the component of the payload like GPS sensor this main component for giving information or data to the ground. The GPS that transmitted to the groung is latitide and longitude. Where the position of the payload to track the location. For tracking using haversing and bearing formula. And the other side can define the distance between payload and the ground. And for the altitude using barometer sensor. The barometer for define the elevetion or tilt servo using trigonometry formula. Using small microcontroller for minimalize the space. For power supplying system using step down 5V to convert 11.1V batteray. The data will transmitted with telemetry that operate at 915 MHz, using serial communcation.

For the antenna tracker system using GPS too. Why, because for make easy if the antenna change the location. In this system the compass sensor using for define the heading of the antenna and for comparing abot the degree of pan servo. The pan servo using servo 180 degree, and for the elevation or the titlt using 90 degree. The supply for the system using 5V with DC converter from the 11.1V. This controller using many serial communication. The firstly for communication with the GUI, second for recieving the data from the payload by telemery. The third is for recieving the data from the GPS to get location when placement the antenna. The GUI only recieve the data from the arduino mega and show the data that recieved and make data logger.

2.2. Design The Software System

The software in here is about the logic and the algorith to controlling tracking system with some input sensors and serial communication with payload between antenna and the antenna with graphical user interface. The flowchart will explain bellow:

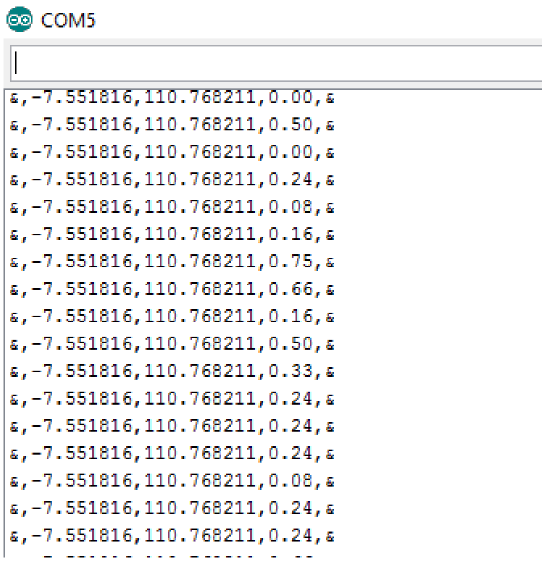


Picture 3. Flochart Antenna Tracker software

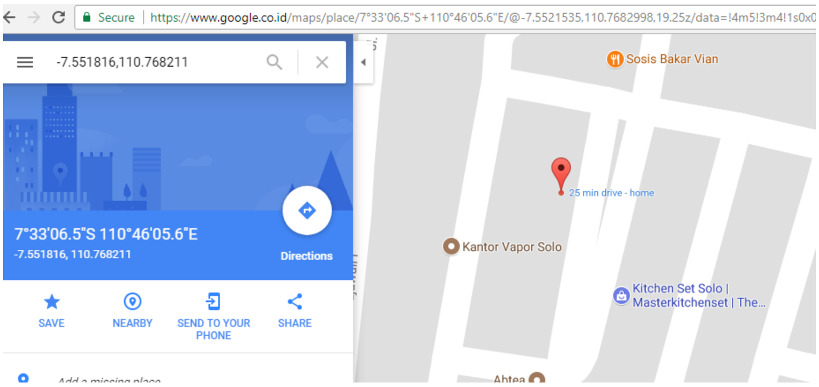
The sourcecode for payload using arduino IDE, that easy to dispalying the serial data for transmitting. The data that made from GPS NMEA code and then parsing to be latitude longitude value. After this will define the value of the altitude using barometer sensor bmp085. For the serial communication set the baud rate at 9600 bps.

2.3. Payload Source Code

The firstly from this activity is how to design the payload has a coordinate system and the altitude meter. Because the payload should be transmitte the data to the antenna or ground station to tracking. For understanding the posision of the payload using GPS sensor that the data is abot latitude and longitude. But for the altitde of the payload using barometer sensor. This GPS sensor connected to the arduino using serial communication, and the barometer using I2C. And then there is the result of payload data’s.

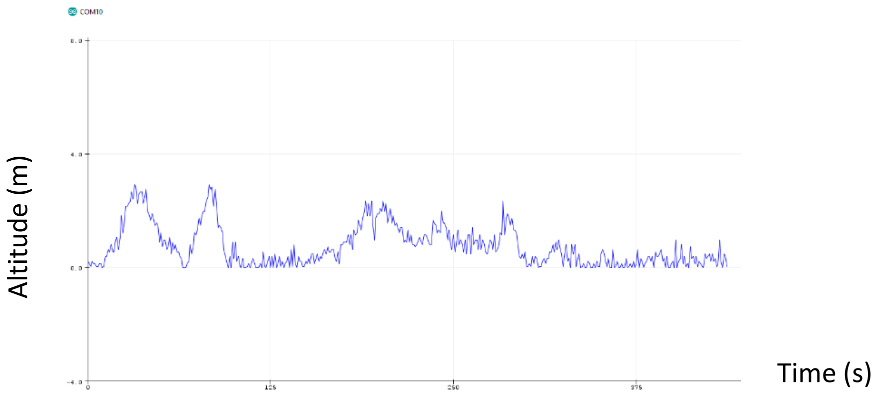


Picture 4. Data From Payload



Picture 5. Location From Payload via Google Map

The first data is latitude, follow the longitude and the altitude of the payload. This the first. Why the code has a *&(and)* and , *(coma)* its some trick to make easy when the antenna recieve complete data start from & and the ending is &. So clearly the data that transmitted of serial communication always corrupted, this trick only make sure the data complete and ready to execute.



Picture 6. Altitude Testing

From the picture 6 there is the result of reading barometer sensor for altitude. The test of measurement start from 0 until 3 meter. The sensor will work fine if the altitude more than 1,5 meter. Usually the barometer sensor work is measure the absolute pressure of the air around them. Utilizing air pressure from sea level for determined the altitude. The altitde will start from sea level, but in this activity the level of the payload start from 0 meter when the power connected to the system. In the code of program has program to controlling the altitude should be start fom 0 when the power connected.

2.4. Antenna Tracker Source Code

The second is the antenna flowchart, this system is as reciever from the payload, the controlling motor, and as transmitter to the graphical user interface. In the firstly, the antenna system will indentify the coordinate or location where this stay. After that the compass will follow to the identifying of heading the antenna. After that will recieve the data from the payload and will calculate some mathematical quation like bearing, haversine, the rigonometry.

```
void loop() {
//check data from payload
  while (Serial1.available())
    {
     if(Serial1.available()>0)
     {
       char inChar = (char)Serial1.read();
       Data_masuk += inChar;
       if (inChar == '\n')
       {
         D_Pisah = true;
       }
    }
   if(D_Pisah)
     {
       Pisah_Data();
       D_Pisah=false;
       Data_masuk="";
     }
    }


       while (Serial2.available() > 0)
   if (gps.encode(Serial2.read()))

     if (millis() > 1000 && gps.charsProcessed() < 10);
```

Picture 7. Sourcecode Reciecving data

```
/value of bearing bearing
  X=(cos(PLat)*sin(PLong-ALong));
  Y=(cos(ALat)*sin(PLat)-sin(ALat)*cos(PLat)*cos(PLong-ALong));

  bearing1=180*7/22*atan2(X,Y);

  if (bearing1<0){
     azimuth=180+bearing1;
  }
  else if (bearing1>=0){
          azimuth=bearing1;
  }

/haversine formula (distance payload antenna)
  ToRad = PI/180.0;

  R = 6378140;                  //earth radius (meter)
  x1 = (PLat-ALat) * ToRad;
  y1 = (PLong-ALong) * ToRad;

  a = sin(x1/2) * sin(x1/2) + cos(ALat * ToRad) * cos (PLat * ToRad) * sin(y1/2) * sin(y1/2);
  c = 2 * atan2(sqrt(a),sqrt(1-a));   //nilai c
  d = R * c;    //value of distance

/value of compass
  kompas = (Compass.bearing());
```

Picture 8. Sourcecode Haversine & Bearing

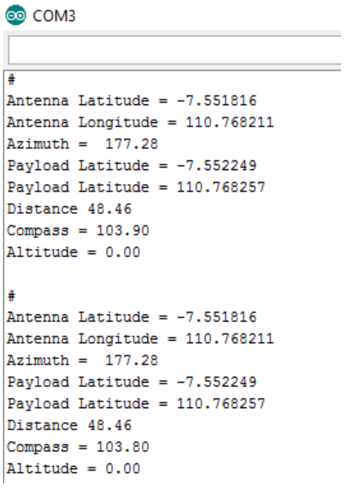
```
//Servo pan
  sudutmax=180;
  maxim=180;
  minim=0;
  azimuth=bearing1;

  sudut=(((maxim-minim)/sudutmax)*(180-azimuth)+20);

  servopan.write(sudut);
  delay(55);
```

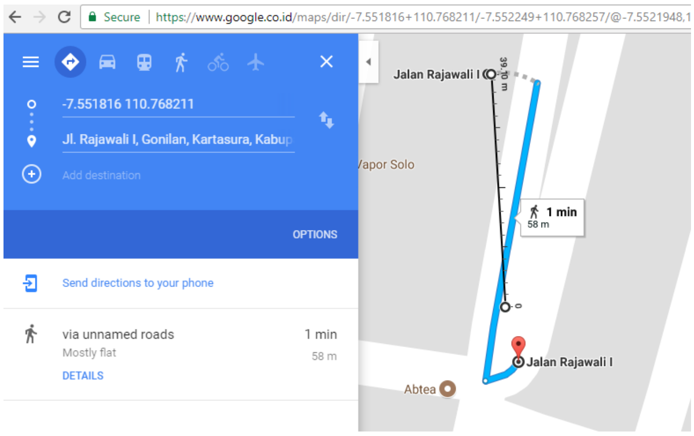
Picture 9. Sourcode Servo Pan

```
//Altitude Payload
    Alt = DM_Prosses[3].toFloat();
    if(Alt<=0)
    {Alt=0;}


   //Altitude servotilt , elevator
   Elevator = Alt/d;
   tan(Elevator);

   Esudutmax=90;                //servo spec 90 degree
   Emax=90;                    //calibrasi maximum 180 degree
   Emini=0;                    //calibrasi minimum 0 degree
   SudutElevator= tan(Elevator);

   Esudut= (((Emax-Emini)/Esudutmax)*(90-SElevator)+20);
   servotilt.write(Esudut);
```

Picture 10. Sourcode Servo Tilt

Like up there is the mathematical enquation for controlling the value input and the value output, sevo motor. The picture 7. about the recieving data from the payload to the antenna tracker system, using separation logic, it make sure the data is complete uncorupted if it to execute. The picture 8 is the formula of the bearing and haversine to define the value that can controlling the servo motor and the heading of the antenna. The picture 9 is the formula for controlling the pan servo, that i the important tracker to make the antenna always line of sight. This pan servo using 180 degree, so the antenna only can track 0-180 degree. The picture 10 is the calculation for determine the elevation degree of the altitude of payload, there is using trigonometry equation and the servo can operate at 0-90 degree.

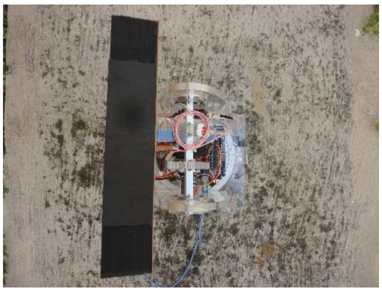


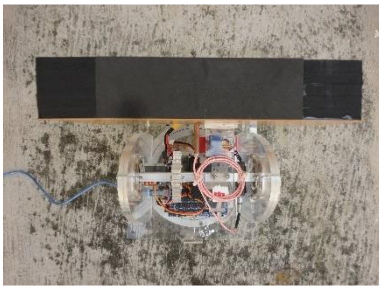


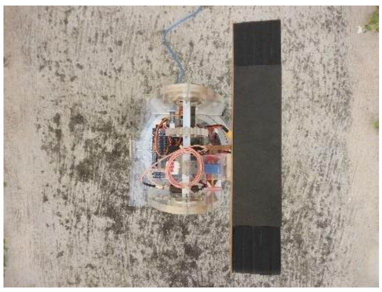
Pictire 11. Data from Antenna Tracker

Picture 12. Distances correction with GooleMap

For controlling the servo pan is using bearing data, and for correction the degree of the servo using data from the compass. Firstly should be now the 0 degre of the compass an the servo pan. Make the sourcecode for controlling the servo that can installed in the frame of antenna tracker and the reading of compass sensor.





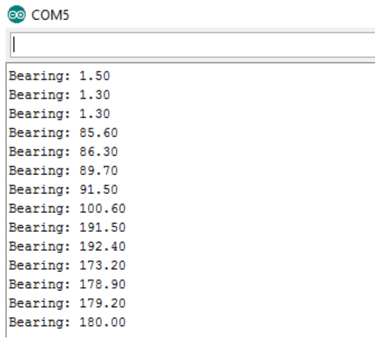


Picture 13. 0º Servo

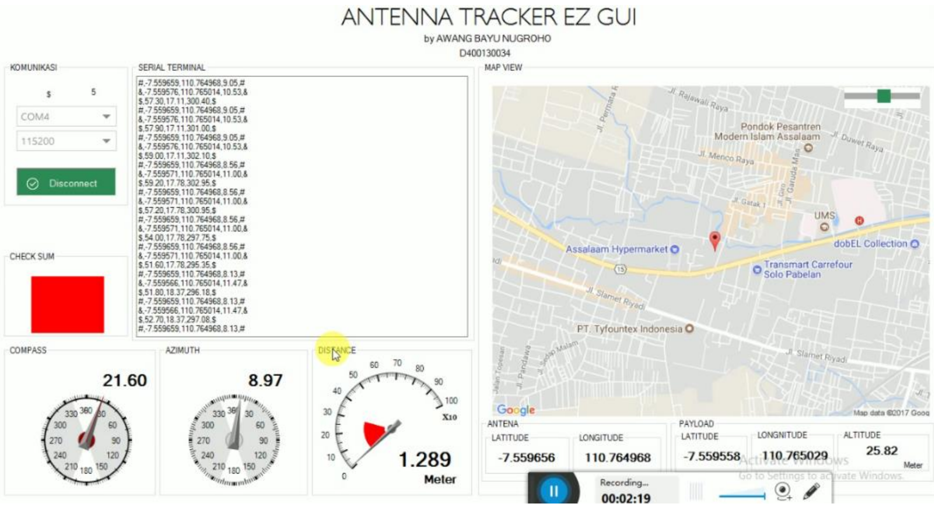
Picture 14. 90º Servo

Picture 15. 180º Servo

This antenna frame was rotate with the servo motor based on the bearing, so the antenna will follow the motor servo rotation. The rotation depend the value of degree from the servo. And then the reading for compass sensor, to make sure the heading of the antenna frame that installed sensor compass is right.



Picture 2.16. Compass Sensor



Picture17. Graphical User Interface

Like the picture 17 there is the display system of the antenna tracker, any gauges, map, and character of value the coordinates. Not forget about the serial communication menus. And the data that recieved will showing in the some window. This graphical user interface build in the pc or the laptop unit. In the other hand after the data displaying inthe graphical user interface by directly the data will saved in to the local disk that determined by program. And the logger will close if the communication disconnected.

For the test antenna tracker, check all the component is coreect by inthe pin main controll. The sensors, power supply and the actuator. Make sure too the telemetry using antenna module before given electricity. Then the payload and the antenna tracker system connected by batteray supply. Because using servo 180, the antenna should be +90 from the heading of compass. So the servo can moving 180 degree in the value of compass from 0-180 degree. After that the open the graphical user interface in the laptop unit. Connect the serial communication with check the COM and baudrate that determined. The baudrate from tracker system with pc suing 115200 bps. And wait few second the data will displaying inthe graphical user interface. After the GPS sensors getting the coordinates, bring the payload walking arround half of circle from the antenna tracker.

3. RESULT AND DISCUSS

The main goal of this project is how to make the directional antenna always line of sight with the payload or the vehicle. Usually the antenna directional has a limitiation in the polarization. And then should be make same system that can track of the object, then the communication can be more longger and focus. After the antenna tracker ready, the antenna tracker tried more than 3 places. The basic of this research is about the location of GPS sensors and and the controll system. The will analyize how about the commnucaton between 2 GPS sensors and the motor as the actuator unit.

3.1. Result of Distance Measurement

The tracking system using arduino platform to make easy from the serial communication check and the source that free. Many libraries from the sensors and the actuators is easy to code with arduino platform. This project that analyze is the distance with different places and the bearing of the compass comparing with the servo pan degree. Include the barometer as the altitude measurement, will analyze how about the error that happen. And this project using biquad antenna, because the biquad antenna the tolerance eror is so big. So, if made the antenna without tuning it will make the polarization still good condition. The firstly, will show the result of the distance of the payload and the antenna tracker. How about the differences, from here will can get resolutions of the GPS sensors.

Table 1. Distance measurement

No	Antenna Latitude	Antenna Longitude	Payload Latitude	Payload Longitude	Distance from GUI (m)	Real Distance (m)	Error
1	-7.551833	110.768211	-7.551813	110.768348	7.13	8	10.6%
2	-7.551855	110.768234	-7.551769	110.768348	14	15	6.6%
3	-7.551855	110.768234	-7.551785	110.768330	11	10	10%
4	-7.559656	110.764968	-7.559354	110.765075	35.2	35.3	2.8%
5	-7.559656	110.764968	-7.559314	110.765143	43	42	2.3%
6	-7.559656	110.764968	-7.559250	110.764906	45.2	45.8	1.3%
7	-7.559656	110.764968	-7.559182	110.765310	63.2	64.4	1.8%
8	-7.559656	110.764968	-7.558945	110.764932	72.5	73.3	1%
9	-7.559656	110.764968	-7.559014	110.764562	84	84.3	0.3%
10	-7.559656	110.764968	-7.558834	110.764492	103.8	104.4	0.5%
Average							3.72%

From the table we can get then date about the distance of the payload and antenna based the GPS sensors coordinate. The distance taken from the data longger inthe graphical user interface. The real measurement of the real distance based from the aplication google map. Clearly the real distance using meter rope, but its hard to define the coodinates. The measurement from the 2 GPS more long than the real condition. And the averange of the error basend the result get the error is 3.72%.

3.2. Result of Azimuth Between Compass Measurement

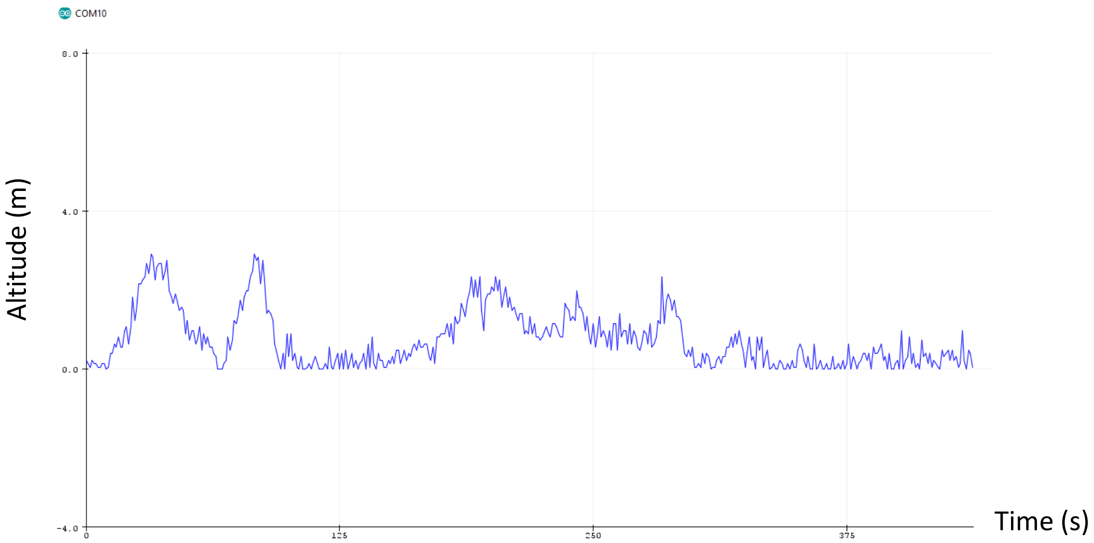
The second is result about the bearing, where the bearing of the servo will compare with the bearing of the compass in the antenna tracker system. From this we can get how much the error of the servo between the compass. The degree of the servo determined by the azimuth. This data taken by ramdomly, measurement of the azimuth servo 180^o compare with the compass, almost same, only small different numbers. From this experiment the number error of the servo is very small.

Table 2. Azimuth And Compass Measurement

No	Antenna Latitude	Antenna Longitude	Payload Latitude	Payload Longitude	Azimuth (º)	Compass (º)	Error
1	-7.551833	110.768211	-7.551813	110.768348	0.00	0.00	0%
2	-7.551855	110.768234	-7.551769	110.768348	12.3	12.4	0.8%
3	-7.551855	110.768234	-7.551785	110.768330	26	26.4	1.5%
4	-7.559656	110.764968	-7.559354	110.765075	58.6	58	1%
5	-7.559654	110.764967	-7.559314	110.765143	89.6	90	0.4%
6	-7.559655	110.764966	-7.559250	110.764906	162	162.4	0.5%
7	-7.559656	110.764968	-7.558834	110.764492	175.4	178.3	1.6%
Average							1%

3.3. Result of the Altitude Measurement

The altittude tobe important if the tracker need elevation of degree in the tracking system. For this result only get the data from the payload measurement directly. Usually very hard to measurement if make the payload go to 20 meter vertically into the air. The altitude sensor using barometer bmp085.



Picture 1. Graph of Altitude

Table 3. Altitde Measurement

No	Altitude BMP085 (m)	Real Antitude (m)	Error
1	0.00	0.00	0%
2	0.00	0.10	100%
3	0.34	0.50	32%
4	0.56	0.70	20%
5	0.76	1.00	24%
6	1.35	1.50	10%
7	1.78	1.70	4.7%
8	1.89	2.00	5.5%
9	2.30	2.50	8%
10	3.12	3.00	4%
11	3.7	3.5	5.7%
12	4.2	4	5%
13	4.7	4.5	4.4%
14	5.3	5	6%
15	5.8	6	3.3%
Average			21%

This measurement test by the altitude at 0-6 meter, from the data only get a sampling data, because many noise that can define. Many noise or the measurement not accurate if the altitude lower than 1 meter. So can concluded the altutide sensor for the payload will work better if the altitude more than 1 meter. This measurement using manually, the payload bring to the up as high 6 meter. And the data were recorded in the serial monitor of the arduino IDE.

3.4. Global Analyze & Discuss

From all the experiment and the result that get, the antenna tracker included working. From the measurement of the GPS still high resolution if the measurement lower 100 meter. The GPS sensors need minimal of the trasnmitter coordinate for working. So the sensor should be in outdoor condition to keep the signal from GPS transmitter. Clearly the GPS sensor many noise in the air, the noise include wind, the buildings, tree and all that can distrub the radiation of the signal. For getting the better data from the GPS shuld be waiting until 30 minutes. Because the GPS will in condition 3d fix. If the GPS reciever getting only 3 satlelites, the data only assumtion, not real. The GPS receiver gets a signal from each GPS satellite. The satellites transmit the exact time the signals are sent. By subtracting the time the signal was transmitted from the time it was received, the GPS can tell how far it is from each satellite. The GPS receiver also knows the exact position in the sky of the satellites, at the moment they sent their signals.

The bearing for the antenna tracker was working, but exactly the actuator motor should be can rotate 360 degree, so the antenna can moving arround by circlely, but it depend for users too. The servo can work if given the value of PWM with variable witdh. There is a minimum and a maximum pulse and repetition rate.in this project the motor servo that used is 180 degree for pan and the tilt is 90 degree. The servo has a neutral position, the neutral position is defined as the position, where the servo has the same amount of potential rotation in the both the counter-clockwise or the clockwise direction.

The altitude sensor usually using bar paramater to define the altitude of the payload. In this project the altitude calculate when the power is connected in the payload, and the sensor will woking and calculate the changes of the pressure. In this measurement still any number of error, its called by the resolution barometer sensor. From the data the sensor can work almost properly, if the altitde more that 1 meter. So can get conlcusion the barometer sensor the number of resolution arrange 1 meter from point where the pauload is started.

4. CONCLUSION

From this activity the antenna tracker is working. But still any unaccurated value about the about the measurement the distances using 2 GPS sensors. Excaxtly this is about the precision of the GPS modules it self. Next the GPS need a minimum of the satlelites, minimum is 8-12 work working properlly. For this system if the models that tracking is some rocket or the aircraft should be using better GPS sensor. Because if the payload for getting location coordinate is very low can distrub the tracking systems.

The actuator of the antenna tracker has a small error. Usually its not about error its about resolution of the two devices the compass sensor and the servo motor. This resolution will influence the antenna fram moving, and the radiation of the antenna. So if the radiaton of the antenna directional is very small degree the updating data coordinates should be moving fast, and it will act by the motor. About the actuator or the motor can using 360 degree its can make the antenna more frexibelly for moving.

The altitude meter calculate from the barometer sensor. This barometer sensor determined for servo tilt using trigonometry calculation. The antenna tracker like angle of elevation, so the calculation engle of the elevation is the altitde per distance. It number will write to value of the servo tilt. For the tilt system in the antenna tracker 90 degree is enough fo tracking the altitde.

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